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(54) Curable resin compositions containing silica-coated microparticles of a cured organosiloxane composition

Härtbare Harzzusammensetzungen, die mit Kieselsäure beschichtete Mikroteilchen einer gehärteten Organosiloxanzusammensetzung enthalten

Compositions durcissables contenant des microparticules recouvertes de silice d'une composition organosiloxane durcies

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(56) References cited:
EP-A- 0 298 743
EP-A- 0 548 969
US-A- 5 064 894
EP-A- 0 516 057
EP-A- 0 647 672

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Description

[0001] This invention relates to very flowable and easily moldable curable resin compositions filled with particles of a cured organosiloxane material. In another aspect, it relates to the very flexible and highly thermal shock-resistant cured resins obtainable from these compositions.

[0002] Curable resin compositions have excellent electrical properties, including dielectric properties, volume resistivity and breakdown strength. These compositions also have excellent mechanical properties that include flexural strength, compressive strength and impact resistance. For these reasons, such resin compositions are used in the widest range of industries.

[0003] When curable resin compositions are used as coatings or adhesives, they cure into products that are stiff and poorly flexible. These compositions also suffer from a large cure shrinkage, which causes such problems as the generation of gaps between the cured resin and its substrate or cracking in the cured resin itself. Additional problems occur in the application of these compositions as sealing resins for electrical and electronic devices because the resins obtainable by curing these compositions have much larger coefficients of thermal expansion (CTE) than the electrical and electronic devices. When the device sealed by a cured resin is repeatedly subjected to thermal shock, problems can occur such as the development of gaps between the cured resin and the device, the appearance of cracks in the cured resin, and even destruction of the device itself. Device reliability is substantially degraded as a result of these problems.

[0004] Many organosiloxane powder-filled curable resin compositions have been disclosed with the goal of improving the flexibility and thermal shock-resistance of cured resins. For example, curable resin compositions, filled with a cured organosiloxane powder (CSP), are disclosed in JP-A(s) 58-219,218; 59-96,122; 64-4,614; and 64-51,467. These documents are representative of the prior art.

[0005] The particles that constitute the CSPs disclosed in this art have a strong tendency to aggregate and are poorly dispersible in curing resins. As a result, the corresponding curable resin compositions exhibit poor flow and molding characteristics. Moreover, the cured resins obtained from these compositions still exhibit a poor flexibility and thermal shock resistance.

[0006] With the goal of improving the flexibility of the cured resins, curable resin compositions have also been proposed in the art that are filled with a powder form of a polymer wherein the particles are coated with (a) an inorganic sol or (b) particles of an ion-exchanger resin. This art is represented by JP-A(s) 4-225829; 5-39313; and 5-25324. Unfortunately, the cured resins obtained by curing these compositions have a poor heat resistance and poor moisture resistance while still exhibiting a poor flexibility.

[0007] EP-A 647 672 which is prior art according to Article 54 (3) and (4) EPC describes a composition comprising (A) a cured silicone powder having a number average particle diameter of 0.1 to 200 micrometers; and (B) an amorphous silica micropowder having an average particle diameter not exceeding 1 micrometer and a surface silanol group density of at least 2 silanol groups per 1 nm^2, wherein said silica micropowder is immobilized on the surface of said cured silicone powder. The composition can further comprise an organic resin, eg an epoxy resin.

[0008] EP-A 0 516 057 relates to silicone rubber particulates, wherein silicone rubber particulates with an average particle diameter of 4 micrometers are coated with metal oxide particles, eg silicon oxide microparticles, prepared from a silicon oxide sol having an average particle diameter of 0.01 to 0.02 micrometers. This silicone rubber particulate was added to a phthalic acid resin paint.

[0009] US-A 5 064 894 discloses organopolysiloxane particulates having a mean particle size ranging from 50 pm to 3 mm, comprising (A) a dihydroxydiorganopolysiloxane; (B) a crosslinking agent; (C) a tin curing catalyst; (D) a surfactant; and (E) a pyrogenic or precipitated silica powder which concentrates at the surface of said particles upon heating. The silica powder has a specific surface area of at least 50 m^2/g and a mean primary particle size of less than 80 nm.

[0010] An objective of the present invention is to provide highly flowable and moldable curable resin compositions that are cured to yield very flexible and highly thermal shock-resistant cured resins. Another objective is to provide methods for preparing these curable compositions.

[0011] These objectives are achieved by incorporating silica-coated microparticles of organosiloxane elastomers or gels into curable resin compositions. The size of the organosiloxane and silica particles are within specified limits.

[0012] This invention provides a curable resin composition comprising

(I) 100 parts by weight of a curable resin, and

(II) from 0.1 to 200 parts by weight of a cured organosiloxane comprising

(A) cured organosiloxane material having an average particle diameter of 0.1 to 200 micrometers wherein the surface of the particles constituting said material contain immobilized microparticles of

(B) an amorphous silica that have a surface silanol group density of at least 2 per 1 nm^2 (100 square ang-

stroms), an average particle diameter not exceeding 1 micrometer, and a BET specific surface area of at least 50 m^2/g.

[0013] The curable resin, ingredient (I) of the present composition, is the basic building block of these compositions, and no particular restrictions apply as to its type.

[0014] Examples of suitable resins are epoxy resins such as bisphenol epoxy resins, phenol novolac epoxy resins, cresol novolac epoxy resins, ortho-cresol novolac epoxy resins, alicyclic epoxy resins, biphenyl epoxy resins, aralkyl epoxy resins, halogenated epoxy resins, triphenolmethane epoxy resins, and naphthol epoxy resins; phenol resins such as phenol novolac resins, cresol novolac resins, naphthol resins, aralkylphenol resins, and triphenol resins; polyimide resins such as bis-maleimide-triazine polyimide resins, wholly aromatic polypyromellitimide-type polyimide resins, polyamino-bis-imide-type polyimide resins, polyamideimide-type polyimide resins, and polyetherimide-type polyimide resins; silicone resins, formaldehyde resins, xylene resins, xylene-formaldehyde resins, ketone-formaldehyde resins, furan resins, urea resins, melamine resins, alkyd resins, unsaturated polyester resins, aniline resins, sulfonamide resins, mixtures of two or more of the preceding curable resins, and copolymeric resins obtained from mixtures containing two or more of the preceding curable resins.

[0015] Ingredient (I) preferably comprises at least one type of curable resin selected from epoxy resins, phenol resins, polyimide resins, and silicone resins. The curing mechanism for ingredient (I) is not critical.

[0016] Typical curing reactions require heating, ultraviolet radiation, or moisture to achieve curing. The physical state of ingredient (I) at room temperature is likewise not critical. This ingredient can be in the form of a liquid or solid at room temperature.

[0017] The cured organosiloxane comprising ingredient (II) improves the flexibility and thermal shock resistance of the cured resin, and does so without reducing fluidity and moldability. Ingredient (II) comprises particles of an elastomeric or gel-type cured organosiloxane material having an average particle diameter of 0.1 to 200 micrometers. Immobilized on the surfaces of these particles is a microparticulate form of amorphous silica having a surface silanol group density of at least 2 per 1 nm^2 (100 square angstroms), an average particle diameter not exceeding 1 micrometer, and a BET specific surface area of at least 50 m^2/g.

[0018] The cured organosiloxane material, part (A) of ingredient (II) must have an average particle diameter of 0.1 to 200 micrometers. The silica microparticles, part (B), cannot be acceptably immobilized on the surface of a cured organosiloxane material having an average particle diameter less than 0.1 micrometer. Curable resin compositions filled with that type of cured organosiloxane material have poor flowability and moldability, and the counterpart, cured resins exhibit a poor flexibility and/or thermal shock resistance.

[0019] Cured organosiloxane material with an average particle size in excess of 200 micrometers is very poorly dispersible in ingredient (I), and the resulting composition also has a very poor flowability. The shape of the particles that constitute part (A) of ingredient (II) is not critical, and may be spherical, flat, or amorphous. A spherical shape is preferred.

[0020] The microparticles of silica that constitute part (B) of ingredient (II) must have the following properties: the density of silanol groups on the surface of the microparticles must be at least 2 per 1 nm^2 (100 square angstroms), the average particle diameter must be no larger than 1 micrometer, and the BET specific surface area must be at least 50 m^2/g.

[0021] Amorphous silica that fails to fulfill any of these requirements cannot achieve adequate bonding to the surface of the particles of cured organosiloxane material that constitute part (A) of ingredient II.

[0022] The shape of the amorphous silica is also not critical, and may be spherical, flat, or amorphous with spherical being preferred.

[0023] The amorphous silica microparticles comprising part (B) can be manufactured by dry methods, electric arc methods, or wet methods. The fumed silicas fabricated by dry methods are preferred for their high purity and low content of impurities such as alkali ions or halogen ions.

[0024] The silanol group density on the silica surface of part (B) is calculated from the BET specific surface area, and the silanol group content is calculated from the amount of hydrogen evolved after part (B) is dried for 3 hours at 120° C under a vacuum of at least 2 kPa (15 mm Hg), and the surface silanol is reacted with lithium aluminum hydride.

[0025] No specific restrictions apply to the method for preparing ingredient (II). The following two methods are provided as examples: (i) first heating a water-based dispersion of parts (A) and (B) and thereafter removing the water; and (ii) subjecting the mixture of parts (A) and (B) to a rubbing unification.

[0026] The water-based dispersion of parts (A) and (B) used in method (i) is prepared by mixing part (B) into a water-based dispersion of part (A), or by mixing a water-based dispersion of part (B) into a water-based dispersion of part (A).

[0027] Water-based dispersions of part (A) are prepared by first preparing the water-based dispersion of a curable organosiloxane composition, and by thereafter curing the composition to produce a cured organosiloxane powder.

[0028] Curable organosiloxane compositions suitable to prepare part A of ingredient II are known. Examples include addition reaction-curing organosiloxane compositions, condensation reaction-curing organosiloxane compositions, or-

ganoperoxide-curing organosiloxane compositions, and ultraviolet-curing organosiloxane compositions.

[0029] The addition reaction-curing and the condensation reaction-curing organosiloxane compositions are preferred for their ease of handling.

[0030] The required ingredients for addition reaction curable organosiloxane compositions include

(a) an organopolysiloxane containing at least 2 alkenyl groups in each molecule,
(b) an organohydrogenpolysiloxane containing at least 2 silicon-bonded hydrogen atoms in each molecule, and
(c) a platinum catalyst.

[0031] These compositions may contain optional ingredients such as (d) one or more fillers and (e) epoxy-functional or aryl-functional organic compounds.

[0032] Ingredient (a) is the base ingredient of addition reaction-curing organosiloxane compositions, and it must contain at least 2 alkenyl radicals in each molecule. The alkenyl radicals are exemplified by vinyl, allyl, propenyl, butenyl, pentenyl, hexenyl, heptenyl, octenyl, nonenyl, and decenyl. The vinyl radical is particularly preferred. The non-alkenyl silicon-bonded organic groups in ingredient (a) are monovalent hydrocarbon radicals, including alkyl such as methyl, ethyl, propyl, and butyl; cycloalkyl such as cyclopentyl and cyclohexyl; aryl such as phenyl, tolyl and xylyl; aralkyl such as benzyl, phenethyl, and 3-phenylpropyl; and haloalkyl groups such as 3-chloropropyl and 3,3,3-trifluoropropyl. Of these radicals, methyl and phenyl are particularly preferred.

[0033] The molecular structure of ingredient (a) is not critical and is exemplified by straight-chain, cyclic, network, and partially branched, straight-chain structures and by mixtures of the preceding. Ingredient (a) is preferably straight-chain to obtain gel-like or rubbery properties for this ingredient.

[0034] Ingredient (a) should have a viscosity at 25° C that permits formation of a water-based dispersion of the addition reaction-curing organosiloxane composition. Suitable viscosities range from 1 mPa.s (centipoise) to the viscosity of the high-viscosity gums. The viscosity of ingredient (a) at 25° C is preferably from 20 to 100,000 mPa.s, most preferably from 20 to 10,000 mPa.s.

[0035] Ingredient (b) is a cross-linker for addition reaction-curing organosiloxane compositions, and must contain at least 2 silicon-bonded hydrogen atoms in each molecule. The silicon-bonded organic groups in ingredient (b) are selected from the same group of non-alkenyl radicals that are present in ingredient (a).

[0036] The molecular structure of ingredient (b) is not critical and is exemplified by straight-chain, cyclic, network, and partially branched straight-chain structures and by mixtures of the preceding. Ingredient (b) should have a viscosity at 25°C that permits the formation of a water-based dispersion of subject addition reaction-curing organosiloxane compositions. This viscosity is preferably from 1 to 10,000 mPa.s.

[0037] Ingredient (b) is added to our addition reaction-curing organosiloxane compositions in a quantity sufficient to induce the cure of said compositions. In specific terms, ingredient (b) is preferably added at 0.3 to 100 parts by weight per 100 parts by weight ingredient (a).

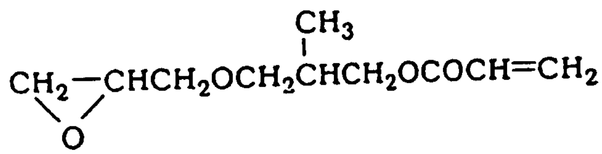
[0038] Ingredient (c) of our addition reaction-curing organosiloxane compositions is a catalyst that accelerates or promotes curing of the compositions by accelerating the addition reaction between the alkenyl groups in ingredient (a) and the silicon-bonded hydrogen atoms in ingredient (b). Any of the well-known platinum catalysts can be used as ingredient (c). Suitable catalysts are chloroplatinic acid, alcohol solutions of chloroplatinic acid, olefin/chloroplatinic acid complexes, chloroplatinic acid/alkenylsiloxane complexes, platinum black, and platinum supported on silica.

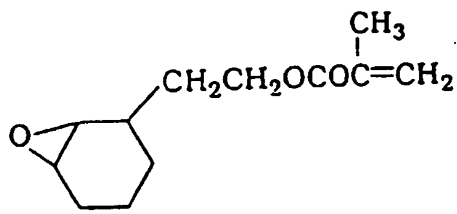
[0039] The concentration of ingredient (c) should be sufficient to accelerate curing of the composition. In specific terms, the concentration of ingredient (c) is preferably equivalent to from 1×10^{-7} to 1×10^{-3} parts by weight of platinum metal per 100 parts by weight of ingredient (a).

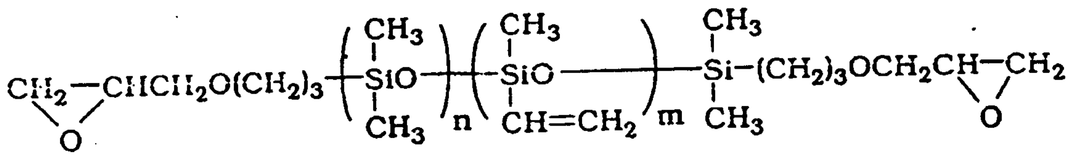
[0040] Filler (d) can be added as an optional ingredient to our addition reaction-curing organosiloxane compositions for such purposes such as adjusting the fluidity of these compositions and improving the mechanical strength of the resulting cured organosiloxane. Examples of ingredient (d) include reinforcing fillers such as precipitated silica, fumed silica, calcined silica, and fumed titanium oxide; and non-reinforcing fillers such as quartz powder, diatomaceous earth, aluminosilicates, iron oxide, zinc oxide, and calcium carbonate.

[0041] Ingredient (d) can be directly blended into our addition reaction-curing organosiloxane compositions, or it can also be added after being treated with a hydrophobicizing organosilicon compound such as hexamethyldisilazane, trimethylchlorosilane or a silanol-terminated polydimethylsiloxane.

[0042] An epoxy-functional organic compound or aryl-functional organic compound, ingredient (e), may also be present as an optional ingredient for the purpose of improving the affinity and bonding between the cured organosiloxane and the organic resin. The epoxy-functional organic compounds encompassed by ingredient (e) are exemplified by allyl glycidyl ether, vinylcyclohexene monoxide, glycidyl acrylate, and glycidyl methacrylate, and by the following:

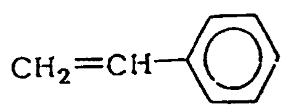


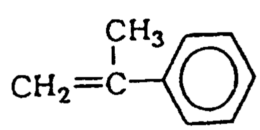


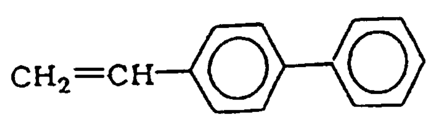


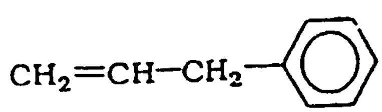
where n and m are positive integers.

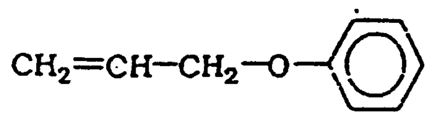
[0043] The aryl-functional organic compounds encompassed by ingredient (e) are exemplified by the-following.

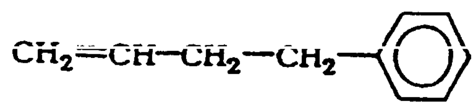


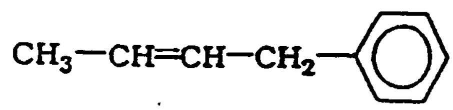


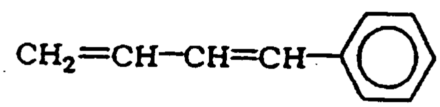


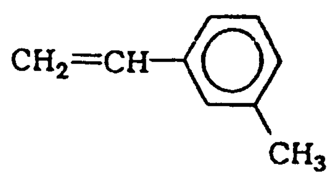












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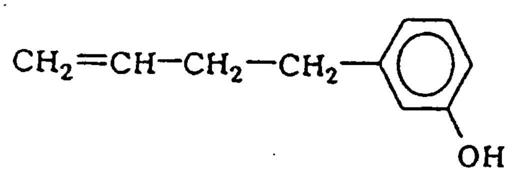

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[0044] Ingredient (e) is added with ingredients (a), (b), and (c), or it can first be reacted with ingredient (b). Ingredient (e) should be added to our organosiloxane compositions in a quantity that will yield an excellent affinity by the resulting cured material for organic resins.

[0045] In specific terms, ingredient (e) is preferably added at 0.1 to 50 parts by weight per 100 parts by weight of ingredient (a).

[0046] Small quantities of an inhibitor may be added to the present addition reaction-curing organosiloxane compositions to adjust their cure rate. These addition-reaction inhibitors are exemplified by acetylenic compounds, hydrazine compounds, triazole compounds, phosphine compounds, mercaptan compounds, and so forth.

[0047] The present compositions can also contain pigments, heat stabilizers, flame retardants, photosensitizers, and diorganopolysiloxanes with alkenyl radicals at only one molecular chain terminal.

[0048] The ingredients of our organosiloxane compositions that cure by a condensation reaction include:

(a') an organopolysiloxane containing silanol groups at both molecular chain terminals, hereinafter referred to as a silanol-endblocked organopolysiloxane,

(b) an organohydrogenpolysiloxane containing at least 2 silicon-bonded hydrogen atoms in each molecule, and
(c') a condensation-reaction catalyst.

[0049] As optional ingredients, these compositions may also contain (d) one or more fillers and (e') at least one silane coupling agent.
[0050] Ingredient (a'), which is the base ingredient of the condensation reaction-curing organosiloxane compositions, is a silanol-endblocked organopolysiloxane. The silicon-bonded organic groups in ingredient (a') are exemplified by monovalent hydrocarbon radicals, which include alkyl radicals such as methyl, ethyl, propyl and butyl; alkenyl radicals such as vinyl, allyl, propenyl, butenyl, pentenyl, hexenyl and decenyl; cycloalkyl radicals such as cyclopentyl and cyclohexyl; aryl radicals such as phenyl, tolyl, and xylyl; aralkyl groups such as benzyl, phenethyl, and 3-phenylpropyl; and haloalkyl radicals such as 3-chloropropyl and 3,3,3-trifluoropropyl.
[0051] The molecular structure of ingredient (a') is not critical and is exemplified by straight-chain, cyclic, network, and partially branched straight-chain structures and by mixtures of these structures. Ingredient (a') is preferably straight-chain to obtain gel-like or rubbery properties for part A of ingredient II.
[0052] Ingredient (a') should have a viscosity at 25° C that permits formation of a water-based dispersion of the condensation curable compositions. Specifically, the viscosity of this ingredient will range from 1 mPa.s (centipoise) to the viscosity of the high-viscosity gums, preferably from 20 to 100,000 mPa.s, and most preferably from 20 to 10,000.
[0053] Ingredient (b) is the crosslinking agent for our condensation reaction-curing organosiloxane compositions, and comprises an organohydrogenpolysiloxane containing at least 2 silicon-bonded hydrogens in each molecule. This ingredient is the same as ingredient (b) described for our addition reaction-curing organosiloxane compositions.
[0054] Ingredient (b) should be added to our condensation reaction-curing organosiloxane compositions in a quantity sufficient to achieve adequate crosslinking of the compositions. In specific terms, the concentration of ingredient (b) is preferably from 0.3 to 100 parts by weight per 100 parts by weight of ingredient (a').
[0055] Ingredient (c') of our condensation curable compositions is a catalyst that promotes curing of the compositions by accelerating the condensation reaction between the silanol groups in ingredient (a') and the silicon-bonded hydrogen atoms in ingredient (b).
[0056] Examples of suitable catalysts include metal salts of organic acids such as dibutyltin dilaurate, dibutyltin diacetate, tin octanoate, dibutyltin dioctoate, tin laurate, ferric stannooctanoate, lead octanoate, lead laurate, and zinc octanoate; organotitanium compounds such as tetrabutyl titanate, tetrapropyl titanate and dibutoxytitanium bis(ethyl acetoacetate); and platinum compounds such as chloroplatinic acid, alcohol solutions of chloroplatinic acid, chloroplatinic acid/olefin complexes, chloroplatinic acid/alkenylsiloxane complexes, platinum black, and platinum supported on silica.
[0057] The catalyst should be added to the condensation curable compositions in a quantity sufficient to accelerate curing of these compositions. In specific terms, the concentration of catalyst is preferably from 0.01 to 10 parts by weight per 100 parts by weight ingredient (a').
[0058] One or more fillers, ingredient (d), can optionally be added to our condensation reaction-curing compositions to adjust the viscosity of the composition and to improve the mechanical strength of the resulting CSP. Suitable fillers are discussed above for ingredient (d) of our addition reaction curable organosiloxane compositions.
[0059] Silane coupling agents and derivatives thereof, ingredient (e'), are optionally present to improve the affinity and bonding between the cured particles of organosiloxane material and organic resins. Ingredient (e') is exemplified by:

vinyltrimethoxysilane,
vinyltriethoxysilane,
vinyl-tris(2-methoxyethoxy)silane,
vinyltriacetoxysilane,
3-chloropropyltrimethoxysilane,
3-aminopropyltrimethoxysilane,
3-aminopropyltriethoxysilane,
3-(2-aminoethyl)aminopropyltrimethoxysilane,
3-mercaptopropyltrimethoxysilane,
3-glycidoxypropyltrimethoxysilane,
2-(3,4-epoxycyclohexyl)ethyltrimethoxysilane,
3-methacryloxypropyltrimethoxysilane,
3-aminopropylmethyldimethoxysilane, and
3-glycidoxypropylmethyldimethoxysilane.

[0060] The concentration of ingredient (e') is sufficient to generate an excellent affinity between the cured organosiloxane particles and the organic resins used as ingredient(I)of the present compositions. The concentration of ingredient

(e') is preferably from 0.1 to 50 parts by weight per 100 parts by weight ingredient (a').

[0061] Other ingredients that can be present in condensation reaction-curing organosiloxane compositions of this invention are pigments, heat stabilizers, flame retardants, photosensitizers, and diorganopolysiloxanes with a silanol group at only one molecular chain terminal. These are similar to the optional ingredients for the above addition reaction curable compositions of this invention.

[0062] One common method for preparing a water-based dispersion containing an addition- or condensation reaction curable organosiloxane composition consists of dispersing the curable composition in water, or an aqueous surfactant solution, and then generating a homogeneous dispersion therefrom by the action of a suitable device such as a homogenizer or colloid mill; or a mixing device such as an ultrasonic vibrator.

[0063] A surfactant is preferably present during preparation of the water-based dispersion of our curable organosiloxane compositions for the purposes of obtaining excellent dispersion stability and reducing the average particle diameter-of the organosiloxane composition. Suitable surfactants include non-ionic surfactants such as polyoxyalkylene alkyl ethers, polyoxyalkylene alkylphenyl ethers, polyoxyalkylene alkyl esters, polyoxyalkylene sorbitan esters, polyethylene glycols, polypropylene glycols, diethylene glycol, and the ethylene oxide adducts of trimethylnonanol; anionic surfactants such as hexylbenzenesulfonic acid, octylbenzenesulfonic acid, decylbenzenesulfonic acid, dodecylbenzenesulfonic acid, cetylbenzenesulfonic acid, myristylbenzenesulfonic acid, and the sodium salts of these acids; and cationic surfactants such as octyltrimethylammonium hydroxide, dodecyltrimethylammonium hydroxide, hexadecyltrimethylammonium hydroxide, octyldimethylbenzylammonium hydroxide, decyldimethylbenzylammonium hydroxide, dioctadecyldimethylammonium hydroxide, beef tallow trimethylammonium hydroxide, and cocotrimethylammonium hydroxide.

[0064] Mixtures of two or more of these surfactants may also be used. More particularly, even smaller average particle diameters for the curable organosiloxane composition in our water-based dispersion can be obtained through the use of a preferred mixture of surfactants comprising two non-ionic surfactants wherein the hydrophobic lipophlic balance number (HLB) of one is less than 10, the HLB of the other is at least 10, and the difference between their HLB values is at least 5.

[0065] The concentration of surfactant is not critical, and is typically from 0.1 to 20 parts by weight per 100 parts by weight of curable organosiloxane composition, preferably from 0.5 to 8 parts by weight per 100 parts by weight of curable organosiloxane composition.

[0066] The amount of water used to form the dispersion is not critical, however the use of 40 to 2,000 parts, preferably from 40 to 1000 parts, by weight of water per 100 parts by weight of curable organosiloxane composition is desirable.

[0067] It is difficult to prepare water-based dispersions using less than 40 parts by weight water per 100 parts by weight of curable organosiloxane composition, while the yield of particles decreases when the amount of water exceeds 2,000 parts by weight.

[0068] The water used to prepare the dispersion preferably has a low concentration of metal and halide ions. An electrical conductivity below 1 micromhos/cm is preferred, and ion-exchanged water with an electrical conductivity below 0.5 micromhos/cm is even more preferred.

[0069] A water-based dispersion of cured organosiloxane material is obtained by heating the dispersed curable composition, or by allowing the dispersion to remain at room temperature. The heating temperature preferably does not exceed 100° C and is preferably from 40° C to 95° C.

[0070] Methods for heating the water-based curable organosiloxane composition dispersion include applying heat to the water-based dispersion or adding hot water to the dispersion.

[0071] The average diameter of the cured organosiloxane particles used to prepare the resin compositions of this invention is from 0.1 to 200 micrometers, preferably from 0.5 to 80 micrometers. The amorphous silica microparticles cannot be acceptably immobilized on the surface of the organosiloxane particles when the average diameter of the cured particles is below 0.1 micrometer. The flowability and dispersibility of the cured organosiloxane powder are substantially reduced when the average particle diameter exceeds 200 micrometers.

[0072] In method (i), the microparticulate form of silica, ingredient (B), or a water-based dispersion of part (B), is blended with the water-based dispersion of the curable resin particles, ingredient (A), to obtain a water-based dispersion of ingredients (A) and (B).

[0073] Part (B) can be homogeneously dispersed in water because it is in the form of amorphous microparticles of silica with a surface silanol group density of at least 2 per 1 nm^2 (100 square angstroms), an average particle diameter not exceeding 1 micrometer, and a BET specific surface area of at least 50 m^2/g.

[0074] In method (i), the amount of silica added is sufficient to become immobilized on the surface of the particles of curable organosiloxane composition that constitute part (A), and will depend upon the particle size of the silica, part (B).

[0075] The amount of silica present is typically from 0.05 to 30 parts by weight per 100 parts by weight of part (A), and preferably from 0.1 to 30 parts.

[0076] The amount of part (B) is preferably from 1 to 15 parts by weight per 100 parts by weight part (A) when the

average particle diameter of part (A) is from 0.1 to 10 micrometers. This amount of part (B) is from 0.5 to 10 parts by weight per 100 parts by weight part (A) when the average particle diameter of part (A) is from 10 to 200 micrometers.

[0077] The next step of method (i) is to heat the water-based dispersion of parts (A) and (B), which causes the particles of silica to become immobilized on the surface of the particles of part (A) by the interaction in the water of the silanol groups on the surface of the silica with the functional groups such as silanol, silicon-bonded hydrogen, and silicon-bonded alkoxy located on the surface of part (A).

[0078] The heating temperature used in this step is not critical, but is preferably from 40° C to 95° C, most preferably from 60° C to 90° C.

[0079] The final step of method (i) is removal of the water from the water-based dispersion of parts (A) and (B) to yield a particulate form of cured organosiloxane [part (A)] bearing microparticles of silica [part (B)] immobilized on the surface of the cured organosiloxane particles.

[0080] Techniques for removing water include drying in an air current and drying in devices such as a vacuum dryer, hot-air convection oven and spray dryer.

[0081] The microparticles of silica used in method (ii) are prepared by removing water, from a water-based dispersion of part (A). Techniques for preparing the dispersion and removing the water are described in preceding sections of this specification.

[0082] Examples of techniques for achieving a blend of parts (A) and (B) by subjecting the ingredients to a shear mixing action, are exemplified by the action of devices such as a ball mill, Henschel™ mixer, stirred mill, Ross™ mixer, planetary mixer, two-roll mill, or a motorized orbiting mortar and pestle mixer.

[0083] Use of Henschel™ mixers, stirred mills, and motorized orbiting mortars and pestles are preferred because they employ relatively high rotational speeds or a high rubbing unification effect.

[0084] The amount of part (B) added in method (ii) is sufficient to immobilize the silica on the surface of the particles of curable composition that constitute part (A), and will depend upon the average particle size of part (A). In specific terms, this amount is preferably from 0.05 to 30 parts by weight, most preferably from 0.1 to 30 parts, by weight of part (B) per 100 parts by weight part (A).

[0085] The concentration of part (B) is preferably from 1 to 15 parts by weight per 100 parts by weight of part (A) when the average particle diameter of part (A) is from 0.1 to 10 micrometers. The concentration of part (B) is preferably from 0.5 to 10 parts by weight per 100 parts by weight part (A) when the average particle diameter of part (A) is from 10 to 200 micrometers.

[0086] When a mixture of parts (A) and (B) is subjected to rubbing unification in method (ii), part (B) becomes strongly immobilized or bound on the surface of part (A) through the interaction of the surface silanol of part (B) with functional groups (e.g., silanol, silicon-bonded hydrogen, silicon-bonded alkoxy, etc.) on the surface of part (A).

[0087] No specific limitations apply to the temperature during the unification by rubbing together particles that constitute parts (A) and (B).

[0088] Part (B) is tightly immobilized on the surface of part (A) in the silica-coated cured organosiloxane particles of ingredient (II) of our compositions. A characteristic feature of ingredient (II) is that it will not readily shed or release the immobilized particles of silica, even when subjected to shearing forces. The strength of the immobilization of part (B) on the surface of part (A) is tested and confirmed by simply subjecting ingredient (II) to high shearing forces in a medium such as water or organic solvent.

[0089] Ingredient (II) has little tendency to undergo aggregation or blocking and also contains very little secondary aggregate. As a result, it will not clog or obstruct processing equipment, including such elements as hoppers, storage bins and the like. It also exhibits an excellent flowability and, in particular, exhibits an excellent dispersibility in ingredient (I).

[0090] The concentration of ingredient (II) is from 0.1 to 200 parts by weight per 100 parts by weight of the curable resin composition of ingredient (I). The cured resin has poor flexibility and thermal shock resistance when the concentration of ingredient (II) is less than 0.1 weight part per 100 parts by weight of ingredient (I).

[0091] At the other end of the concentration range, the fluidity and moldability of the corresponding curable resin composition declines when more than 200 parts by weight of ingredient (II) are present.

[0092] The curable resin compositions of this invention may contain optional ingredients in addition to the ingredients already described above. These optional ingredients include curing agents; cure accelerators; fillers; flame retardants such as bromine compounds and antimony oxide, and coupling agents such as silanes and titanium compounds; mold-release agents such as the metal salts of higher fatty acids and so forth; waxes such as polyesters, carnauba wax, and the like; photosensitizers; plasticizers; pigments and dyes; inorganic and organic ion scavengers; ageing inhibitors; and plasticizers such as polybutadiene and polystyrene.

[0093] Curing agents that can be blended into our curable resin compositions are exemplified by organic acids such as carboxylic acids and sulfonic acids or by their anhydrides; organic hydroxy compounds; organosilicon compounds bearing functional groups such as silanol, silicon-bonded alkoxy, and silicon-bonded halogen; and amine compounds such as primary and secondary polyamines.

These curing agents can also be used in combinations of two or more.

[0094] Cure accelerators are exemplified by carboxylic acids; phenol compounds; alcohols; tertiary amine compounds; reaction mixtures prepared from amine compounds and Lewis acids; and organometallic compounds, such as those of aluminum and zirconium; organophosphorus compounds, such as phosphine, and reaction mixtures prepared from phosphine and Lewis acids; heterocyclic amines; boron complex compounds; organoammonium salts; organosulfonium salts; and organoperoxides.

[0095] Fillers present in the compositions of this invention are fibrous fillers such as glass fiber, asbestos, alumina fiber, ceramic fiber based on alumina + silica, boron fiber, zirconia fiber, silicon carbide fiber, metal fibers, polyester fibers, aramide fibers, nylon fibers, phenol fibers, and plant- or animal-derived natural fibers; granular or particulate fillers such as fused silica, precipitated silica, fumed silica, calcined silica, zinc oxide, fired clay, carbon black, glass beads, alumina, talc, calcium carbonate, clay, aluminum hydroxide, barium sulfate, titanium dioxide, aluminum nitride, silicon carbide, magnesium oxide, beryllium oxide, kaolin, mica, zirconia, and particulate forms of cured resins. Moreover, mixtures of two or more of these fillers can also be used.

[0096] No specific limitations apply to methods for preparing our curable resin compositions. Preparation is performed, for example, by mixing ingredients (I), (II) and any optional ingredients in a device such as a ball mill, Henschel™ mixer, stirred mill, Ross™ mixer, planetary mixer, two-roll mill, motorized orbiting mortar and pestle mixer, and so forth. The Henschel™ mixer, stirred mill, or motorized orbiting mortar and pestle mixer are preferred. Organic solvents may also be used as vehicles for preparing our curable resin compositions.

[0097] Examples of suitable solvents are aromatic organic solvents such as toluene or xylene and aliphatic hydrocarbon solvents such as hexane or heptane.

[0098] With regard to the temperature to which the curable resin composition is exposed during processing in the aforementioned devices heating the compositions from 60° C to 95° C is preferred. Curable resin compositions according to this invention may be ground after their preparation.

[0099] Depending upon the type of reaction used to cure the resin portion of the present compositions, these compositions are cured at room temperature or upon heating, by exposure to heat, ultraviolet radiation, or moisture.

[0100] Heat curable resin compositions are cured by transfer molding, injection molding, or casting. These compositions are preferably cured at 100° C to 300° C and are preferably also subjected to a post-cure at 100°C to 300°C.

[0101] The curable compositions of the present invention are very flowable and highly moldable. They cure to yield resins that are flexible and have excellent thermal shock resistance. These compositions are therefore useful as sealants for electrical and electronic devices, such as IC's, LSI's, transistors and diodes.

Examples

[0102] The following examples describe preferred curable resin compositions and cured resins of this invention. Unless otherwise specified, all parts and percentages are by weight and the reported viscosity values were measured at 25° C. The properties of the cured organosiloxane materials, curable resin compositions, and cured resins were measured using the following procedures.

[0103] The average diameter of the cured organosiloxane materials were determined using an image processor connected to an optical microscope.

[0104] The fluidity of the cured organosiloxane materials was determined by pouring 50 g of cured organosiloxane particles of a size passing through a 0.42 mm (40 mesh) screen from a height of 20 cm and measuring the angle of repose exhibited by the particles.

[0105] Aggregation of the cured organosiloxanes was determined using an air-jet sieve from the Alpine Company and by calculating the percentage of material retained on a 0.04 mm (325 mesh) screen.

[0106] Blocking of the cured organosiloxane particles was determined by placing 100 g of the particles in a tube with a cross section of 10 cm x 10 cm, applying a load of 9.81 N (1 kg_f) to the exposed surface of the particles while orienting the tube in a vertical direction. After standing for 2 days, the load was removed and the sample was divided into 10 portions. Using an air-jet sieve from the Alpine Company, a 10 g portion of the cured organosiloxane powder was passed through 0.15 mm (150 mesh) screen over 5 minutes, and the weight percentage of material remaining on the screen was measured.

[0107] Dispersibility of the cured organosiloxane materials was determined by placing a mixture of 1 g of the cured organosiloxane particles and 50 mℓ of toluene in a 100 mℓ-capacity mayonnaise bottle equipped with a lid. The bottle was shaken 50 times and then allowed to stand for 10 hours. Aggregation of the cured organosiloxane particles was then measured using an image processor connected to an optical microscope.

[0108] 2.0 g of cured organosiloxane materials and 100 mℓ of acetone were stirred for 10 minutes at 4,000 rpm in a homogenizer, and the cured organosiloxane materials were thereafter separated by filtration. The cured organosiloxane was then washed with acetone, dried in an air current, and added to 50 mℓ brine solution exhibiting a specific gravity of 1.3. This blend was mixed for 10 minutes at 4,000 rpm using a homogenizer and then centrifuged. The

amount of silica precipitating as the lower layer was measured, and this weight was reported as a percentage of the silica input for the cured organosiloxane.

[0109] 2.0 g of cured organosiloxane material and 50 g of ion-exchanged water exhibiting an electrical conductivity of 0.4 micromhos/cm were introduced into a pressure cooker and heated at 121° C for 20 hours to extract ionic impurities present in the cured organosiloxane into the water. The sodium and halogen ion concentrations in this aqueous extract were measured by ion chromatography.

[0110] Spiral flow of the curable resin compositions was evaluated based on the method specified in the EMMI standard.

[0111] Molding shrinkage of the curable resin compositions was measured by the method in JIS K-6911. The curable resin composition was cured for 3 minutes at 175°C and was then post-cured for 3 hours at 150°C.

[0112] The coefficient of thermal expansion (CTE) of the cured resins was measured by JIS K-6911.

[0113] The flexural modulus of the cured resins was also measured by JIS K-6911.

[0114] Twenty resin-sealed semiconductor devices were molded using chips with a diameter of 36 mm^2, and a package thickness of 2.0 mm. The moldings were then subjected to heat-cycle testing during which the temperature was varied from -196° C to +150° C over a one minute interval. After 150 cycles, the surface of the resin was inspected with a stereoscopic microscope. The number of moldings in which cracking had appeared in the surface was counted and scored using the following scale:

+ = 5 or less; x = 6 to 10, and x x = 11 or more

[0115] Twenty resin-sealed semiconductor devices were molded using chips with a diameter of 36 mm^2 and a package thickness of 2.0 mm. After being connected to a suitable electrical source the devices were heated for 500 hours in saturated steam (202.6 kpa (2 atm), 121°C). After heating, the number of broken aluminum wires in the devices was determined. The number of moldings was counted and scored using the following scale:

+ = 5 or less; x = 6 to 10, and x x = 11 or more

Reference Example 1

[0116] The following ingredients were blended to homogeneity at -10°C:

50 parts by weight of a dimethylvinylsiloxy-endblocked dimethylpolysiloxane exhibiting viscosity of 800 mPa.s (centipoise), a vinyl equivalent weight of 8,000, a sodium ion concentration ≤ 2 ppm, and a halogen ion concentration ≤ 5 ppm;

11 parts by weight dimethylsiloxane-methylhydrogensiloxane copolymer exhibiting a viscosity of 20 mPa.s, a sodium ion concentration ≤ 2 ppm, a halogen ion concentration ≤ 5 ppm and the formula

$$H-\underset{CH_3}{\overset{CH_3}{Si}}O(\underset{CH_3}{\overset{CH_3}{Si}}O)_{10}(\underset{H}{\overset{CH_3}{Si}}O)_{10}\underset{CH_3}{\overset{CH_3}{Si}}-H$$

2 parts by weight allyl glycidyl ether, and

2 parts by weight vinylcyclohexene monoxide.

[0117] The resultant composition was blended to homogeneity at 5° C with 50 parts by weight of the dimethylvinylsiloxy- endblocked dimethylpolysiloxane and a quantity of isopropanolic chloroplatinic acid solution equivalent to 20 ppm of platinum metal, based on the total amount of dimethylvinylsiloxy-endblocked dimethylpolysiloxane.

[0118] Into the resulting blend were rapidly mixed 200 parts by weight of pure water at 25° C. (conductivity = 0.2 micromhos/cm) and 4 parts by weight polyoxyethylene nonylphenyl ether (HLB = 13.1).

[0119] The mixture was then passed through a homogenizer under a pressure of 29,4·10^6 N/m^2 (300 kg$_f$/cm^2) to yield a homogeneous water-based dispersion of a curable organosiloxane composition. This was held at 30° C for 6 hours, which resulted in curing of the organosiloxane composition and the production of a water-based dispersion of cured organosiloxane particles with an average diameter of 3 micrometers and a perfectly spherical shape. 5 parts by weight fumed silica exhibiting a surface silanol group density of 4.2 per 1 nm^2 (100 square angstroms), a primary particle diameter of 20 millimicrometers, and a BET specific surface area of 200 m^2/g was subsequently added to the water-based cured organosiloxane powder dispersion.

[0120] After blending the ingredients to homogeneity, the resultant dispersion was then heated for 1 hour at 80°C. The resulting water-based dispersion of cured organosiloxane and fumed silica was dried in a spray dryer to yield 110 parts by weight cured organosiloxane recovered from the cyclone separator.

Reference Example 2

[0121] The procedure of Reference Example 1 was followed, with the exception that the fumed silica was replaced with a dimethyldichlorosilane-hydrophobicized fumed silica exhibiting a surface silanol group density of 1.2 per 1 nm^2 (100 square angstroms), a primary particle diameter of 20 nm, and a BET specific surface area of 120 m^2/g. 105 parts by weight of cured organosiloxane was recovered.

[0122] When the hydrophobicized fumed silica was added to the aqueous dispersion of cured organosiloxane particles, silica floated on the surface of the water-based dispersion and a homogeneous water-based dispersion could not be prepared. In addition, the hydrophobicized fumed silica could not be recovered from the cyclone separator during spray drying of the water-based dispersion of cured organosiloxane and hydrophobicized fumed silica. Instead, microparticles that was discharged in the form of a white cloud were collected using a venturi scrubber, and identified as hydrophobicized fumed silica.

Reference Example 3

[0123] Fumed silica exhibiting a surface silanol group density of 4.2 per 1 nm^2 (100 square angstroms), a primary particle diameter of 20 nm, and a BET specific surface area of 200 m^2/g was added to a water-based curable organosiloxane composition, dispersed as described in Reference Example 1, to yield a water-based dispersion containing a curable organosiloxane composition and fumed silica. This water-based dispersion was held for 7 hours at 25° C, at which time an attempt was made to dry the dispersion using a spray dryer. It was found that uncured curable organosiloxane composition had precipitated and drying could not be accomplished.

Reference Example 4

[0124] A curable organosiloxane composition was prepared

from 50 parts by weight of dimethylvinylsiloxy-endblocked dimethylpolysiloxane exhibiting a viscosity of 400 mPa.s, a vinyl equivalent weight of 5,400, a sodium ion concentration ≤ 2 ppm, and a halogen ion concentration ≤ 5 ppm);
1.5 parts by weight of a trimethylsiloxy-endblocked methylhydrogenpolysiloxane exhibiting a viscosity of 20 mPa.s, a silicon-bonded hydrogen equivalent weight of 67, a sodium ion concentration ≤ 2 ppm, and a halogen ion concentration ≤ 5 ppm;
7.5 x 10^{-3} parts by weight of tetramethyltetravinylcyclo-tetrasiloxane; and
a quantity of isopropanolic chloroplatinic acid solution equivalent to 120 ppm of platinum metal based on the total weight of the dimethylvinylsiloxy-endblocked dimethylpolysiloxane.

[0125] 0.25 parts by weight of polyoxyethylene nonylphenyl ether (HLB = 5.7) was added to this curable organosiloxane composition.

[0126] Into the resulting mixture was then added dropwise, over a period of approximately 5 minutes while stirring, an aqueous solution composed of 1 weight part polyoxyethylene octylphenyl ether (HLB = 18.1) and 10 parts by weight of pure water with a conductivity of 0.2 micromhos/cm. After stirring for approximately 1 hour at 600 rpm, the mixture was passed through a colloid mill to produce a thick, water-based dispersion of the curable organosiloxane composition. This water-based dispersion was introduced into sufficient pure water to provide 50 weight percent of organosiloxane ingredient in the water-based curable organosiloxane composition dispersion. Thorough stirring yielded a homogeneous water-based dispersion of curable organosiloxane composition.

[0127] The organosiloxane composition was then cured by maintaining the aqueous dispersion containing the water-based curable organosiloxane composition under ambient conditions overnight. The resultant water-based dispersion of cured organosiloxane particles had an average diameter of 1 micrometer and a perfectly spherical shape.

[0128] 50 parts by weight of a 10% water-based dispersion of fumed silica exhibiting a surface silanol group density of 4.2 per 1 nm^2 (100 square angstroms), a primary particle diameter of 20 nm, and a BET specific surface area of 200 m^2/g was added to the water-based dispersion of cured organosiloxane particles with stirring to homogeneity. Heating for 1 hour at 70° C yielded a water-based dispersion of cured organosiloxane powder + fumed silica. This dispersion was dried in a spray dryer, yielding approximately 58 parts by weight of cured organosiloxane particles recovered from the cyclone apparatus.

Reference Example 5

[0129] Particles of a cured organosiloxane composition were prepared as in Reference Example 4, but in this case omitting the fumed silica.

Reference Example 6

[0130] 50 parts by weight of cured organosiloxane particles were prepared by the procedure in Reference Example 4, but by replacing the fumed silica of Reference Example 4 with 27 parts by weight, equivalent to 20 weight percent, of colloidal silica with an average particle diameter of 30 nm and a sodium ion concentration of 0.03 percent.

Reference Example 7

[0131] A curable organosiloxane composition was prepared by blending to homogeneity

50 parts of a silanol-endblocked dimethylpolysiloxane exhibiting a viscosity 40 mPa.s, a hydroxyl equivalent weight of 450, a sodium ion concentration ≤ 2 ppm, and a halogen ion concentration ≤ 5 ppm;
4.0 parts by weight of trimethylsiloxy-endblocked methylhydrogenpolysiloxane exhibiting a viscosity of 20 mPa.s, a silicon-bonded hydrogen equivalent weight of 67, a sodium ion concentration ≤ 2 ppm, and a halogen ion concentration ≤ 5 ppm), and
0.75 parts by weight dibutyltin dilaurate.

[0132] While maintaining this curable organosiloxane composition at 10° C, it was mixed into 250 parts by weight of pure water exhibiting a conductivity of 0.2 micromhos/cm, and 3 parts by weight polyoxyethylene nonylphenyl ether exhibiting an HLB value of 13.1. The resultant mixture was passed through a homogenizer to yield a homogeneous water-based dispersion of the curable organosiloxane composition. This dispersion was held at 25° C for 10 hours to cure the organosiloxane composition. The particles of cured organosiloxane had an average diameter of 2 micrometers and a perfectly spherical shape.

[0133] 8 parts by weight of fumed silica exhibiting a surface silanol group density of 2.5 per 1 nm^2 (100 square angstroms), a primary particle diameter of 10 nm were added to this aqueous dispersion of cured organosiloxane particles with stirring to homogeneity. Heating the dispersion at 60° C for 30 minutes yielded an aqueous dispersion of cured organosiloxane particles and fumed silica. Drying this dispersion in a spray dryer resulted yielded 55 parts by weight of cured organosiloxane particles recovered from the cyclone separator.

Reference Example 8

[0134] 10 parts by weight of fumed silica exhibiting a surface silanol group density of 4.2 per 1 nm^2 (100 square angstroms), a primary particle diameter of 20 nm, and a BET specific surface area of 200 m^2/g were blended into 100 parts by weight of cured organosiloxane particles prepared as described in Reference Example 5. The resultant mixture was then stirred with an automatic mortar over a period of 5 hours to yield a cured organosiloxane powder.

Table 1

	Ref. Ex.1	Ref. Ex.2	Ref. Ex.4	Ref. Ex.5	Ref. Ex.6	Ref. Ex.7	Ref. Ex.8
average particle diameter (micrometers)	3	3	1	1.5	4	2	2
aggregation (%)	<0.1	52	<0.1	58	<0.1	<0.1	8
blocking (%)	0.1	2	0.1	90	5	0.1	0.1
sodium concentration (ppm)	0.3	0.8	0.5	0.5	35	1.0	0.8
halogen concentration (ppm)	5	10	7	8	17	10	11
angle of repose (degrees)	32	55	34	61	32	30	34

Table 1 (continued)

	Ref. Ex.1	Ref. Ex.2	Ref. Ex.4	Ref. Ex.5	Ref. Ex.6	Ref. Ex.7	Ref. Ex.8
dispersibility (mm)	<0.5	5	<0.5	9	<0.5	<0.5	1.5
silica separation ratio (%)	11	99-100	5	-	85	2	19

Example 1

[0135] The following ingredients were mixed to homogeneity: 100 parts by weight of phenol novolac resin exhibiting a softening point of 80°C, hydroxyl equivalent weight of 100; 20 parts by weight cured organosiloxane powder prepared in Reference Example 1;

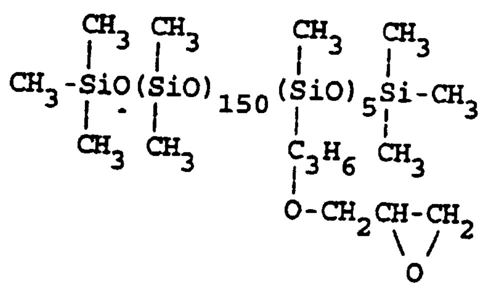
185.7 parts by weight fused quartz powder;
11.4 parts by weight hexamethylenetetramine;1.0 weight part 3-glycidoxypropyltrimethoxysilane, and
2.9 parts by weight carnauba wax.

[0136] Kneading the resultant mixture on a hot roll at 90°C and cooling then yielded a curable resin composition of the present invention. This curable resin composition was subsequently ground and transfer molded for 3 minutes at 175° C under a pressure of $6{,}87 \cdot 10^6$ N/m^2 (70 kg$_f$/cm^2). The cured resin was then post-cured for 2 hours at 150° C.

[0137] The properties of the curable resin composition and the cured resin obtained therefrom are reported in Table 2.

Comparative Example 1

[0138] A comparative curable resin composition outside the scope of the present invention was prepared using the procedure described in Example 1, but replacing the cured organosiloxane of Reference Example 1 with 20 parts by weight of an epoxy-functional organopolysiloxane with the following formula:



[0139] An attempt was made to transfer mold this curable resin composition as described in Example 1, but its cure did not develop to an adequate degree. The result was that the composition remained sticky and adherent and could not be de-molded. The properties of the cured resin could therefore not be measured.

Comparative Example 2

[0140] A comparative cured resin composition outside the scope of the present invention was prepared by the procedure described in Example 1, but in this case entirely omitting the cured organosiloxane of Reference Example 1. The properties of the curable resin composition and the cured resin obtained therefrom are reported in Table 2.

Table 2

	present invention	comparative examples	
	Ex.1	Comp. Ex. 1	Comp. Ex. 2
properties of the curable resin compositions			
spiral flow ((inches/m)) (cm/m) mold shrinkage (%)	(29/0.74) 73.66/0.74 0.05	(>60/.52) >152/0.52 could not be measured	(31/0.79) 78.74/0.79 0.31
properties of the cured resins			
flexural modulus ((kg_f/cm^2)) (N/m^2) CTE (x $10^{-5}/°C$)	(920) $90.2 \cdot 10^6$ 0.6	could not be measured could not be measured	(1350) $132.3 \cdot 10^6$ 1.5

Example 2

[0141] The following ingredients were mixed to homogeneity: 15 parts by weight of cured organosiloxane prepared as described in Reference Example 1;

284.6 parts by weight fused quartz powder;
3.5 parts by weight aluminum acetylacetonate;
1.0 weight part 3-glycidoxypropyltrimethoxysilane;
3.8 parts by weight carnauba wax; and
100 parts by weight of a organosiloxane-epoxy resin consisting of 50 parts by weight ortho-cresol novolac epoxy resin exhibiting a softening point of 60° C and an epoxy equivalent weight of 220; and 50 parts by weight of organosiloxane resin exhibiting a silicon-bonded hydroxyl group content of 5 weight percent and consisting essentially of 40 mole percent $CH_3SiO_{3/2}$ units, 10 mole percent $C_6H_5(CH_3)SiO_{2/2}$ units, 40 mole percent $C_6H_5SiO_{3/2}$ units, and 10 mole percent $(C_6H_5)_2SiO_{2/2}$ units. Kneading this mixture on a hot roll at 90°C and cooling the resultant mixture yielded a curable resin composition of the present invention.

This curable resin composition was subsequently ground and transfer molded for 2 minutes at 175° C under a pressure of $6{,}87 \cdot 10^6$ N/m^2 (70 kg_f/cm^2). The resultant cured resin was post-cured for 12 hours at 180°C. The properties of the curable resin composition and the cured resin obtained therefrom are reported in Table 3.

Example 3

[0142] A curable resin composition of the present invention was prepared according to the procedure described in Example 2, but in this case using the cured organosiloxane prepared in Reference Example 7 in place of the organosiloxane of Reference Example 1. The properties of this curable resin composition and the cured resin obtained therefrom are reported in Table 3.

Example 4

[0143] A curable resin composition of the present invention was prepared according to the procedure described in Example 2, but using the cured organosiloxane prepared in Reference Example 8 in place of the organosiloxane of Reference Example 1 . The properties of this curable resin composition and the cured resin obtained therefrom are reported in Table 3.

Comparative Example 3

[0144] A comparative curable resin composition outside the scope of the present invention was prepared according to the procedure described in Example 2, but using the cured organosiloxane prepared in Reference Example 2 in place of the organosiloxane of Reference Example 1. The properties of this curable resin composition and the cured resin obtained therefrom are reported in Table 3.

Comparative Example 4

[0145] A comparative curable resin composition outside the scope of the present invention was prepared according to the procedure described in Example 2, but in this case entirely omitting the cured organosiloxane of Reference Example 1. The properties of this curable resin composition and the cured resin obtained therefrom are reported in Table 3.

Table 3

	present invention		comparative examples		
	Ex.2	Ex.3	Ex.4	Comp. Ex. 3	Comp. Ex. 4
properties of the curable resin compositions					
spiral flow ((inches/m)) (cm/m)	(34/0.94) 86.36/0.94	(32.0.81) 81.28/0.81	(33/0.84) 83.82/0.84	(21/0.53) 53.34/0.53	(35/0.89) 88.9/0.89
properties of the cured resins					
flexural modulus ((kg_f/cm^2)) (N/m^2) CTE (x 10^{-5}/°C) moisture resistance thermal shock resistance	(980) $96.0 \cdot 10^6$ 1.5 + +	(1000) $98.0 \cdot 10^6$ 1.5 + +	(950) $93.1 \cdot 10^6$ 1.4 + +	(1040) $101.9 \cdot 10^6$ 1.6 + +	(1520) $150.0 \cdot 10^6$ 2.8 xx xx

Example 5

[0146] The following ingredients were mixed to homogeneity: 100 parts by weight of bismaleimide-triazine-type heat-curing polyimide resin; 23 parts by weight of cured organosiloxane prepared in Reference Example 4;

233 parts by weight fused quartz;
3.3 parts by weight carnauba wax;
2.0 parts by weight 3-glycidoxypropyltrimethoxysilane,
and 1.0 part by weight aluminum benzoate.

[0147] Kneading this mixture on a hot roll at 90°C and cooling then yielded a curable resin composition according to the present invention. This curable resin composition was subsequently ground and transfer molded for 4 minutes at 220° C under a pressure of $6{,}87 \cdot 10^6$ N/m^2 (70 kg$_f$/cm^2). The cured resin was post-cured for 3 hours at 230° C. The properties of the curable resin composition and the cured resin obtained therefrom are reported in Table 4.

Comparative Example 5

[0148] A comparative curable resin composition outside the scope of the present invention was prepared according to the procedure described in Example 5, but using the cured organosiloxane prepared in Reference Example 2. The properties of this curable resin composition and the cured resin obtained therefrom are reported in Table 4.

Comparative Example 6

[0149] A comparative curable resin composition outside the scope of the present invention was prepared according to the procedure described in Example 5, but completely omitting the cured organosiloxane powder of Reference Example 4. The properties of this curable resin composition and the cured resin obtained therefrom are reported in Table 4.

Table 4

	present invention	comparative examples	
	Example 5	Comp. Ex. 5	Comp. Ex. 6
properties of the curable resin compositions			
spiral flow ((inches/m)) (cm/m) mold shrinkage (%)	(46/1.17) 116.84/1.17 0.24	(38/0.97) 96.52/0.97 0.31	(40/1.02) 101.6/1.02 0.49
properties of the cured resins			
flexural modulus ((kg$_f$/cm^2)) (N/m^2) CTE (x 10^{-5}/° C)	(950) $93.1 \cdot 10^6$ 1.5	(980) $96.0 \cdot 10^6$ 1.5	(1350) $132.3 \cdot 10^6$ 1.8

Example 6

[0150] The following ingredients were mixed to homogeneity: 75 parts by weight of a ortho-cresol novolac epoxy resin exhibiting a softening point of 60° C and an epoxy equivalent weight of 220;

35 parts by weight of a phenol novolac resin exhibiting a softening point of 80° C and a hydroxyl equivalent weight of 100;
26 parts by weight of cured organosiloxane particles prepared in Reference Example 1;
260 parts by weight fused quartz;
1.0 weight part carnauba wax;
1.0 weight part 3-glycidoxypropyltrimethoxysilane; and
0.6 weight part triphenylphosphine.

[0151] Kneading the resultant mixture on a hot roll at 90°C and cooling yielded a curable resin composition according to the present invention. This curable resin composition was subsequently ground and transfer molded for 3 minutes

at 175° C at $6.87 \cdot 10^6$ N/m² (70 kg$_f$/cm²). The cured resin was post-cured for 5 hours at 180° C. The properties of the curable resin composition and the cured resin obtained therefrom are reported in Table 5.

Example 7

[0152] A curable resin composition of the present invention was prepared by the procedure described in Example 6, but using the cured organosiloxane powder prepared in Reference Example 4. The properties of this curable resin composition and the cured resin obtained therefrom are reported in Table 5.

Comparative Example 7

[0153] A comparative curable resin composition outside the scope of the present invention was prepared according to the procedure described in Example 6, but in this case using the cured organosiloxane particles prepared in Reference Example 6. The properties of this curable resin composition and the cured resin obtained therefrom are reported in Table 5.

Comparative Example 8

[0154] A comparative curable resin composition outside the scope of the present invention was prepared by the procedure described in Example 6, but in this case entirely omitting the cured organosiloxane particles. The properties of this curable resin composition and the cured resin obtained therefrom are reported in Table 5.

Table 5

	present invention		comparative examples	
	Example 6	Example 7	Comp. Ex.7	Comp. Ex.8
properties of the curable resin compositions				
spiral flow ((inches/m)) (cm/m)	51/1.30 129.54/1.30	48/1.22 121.92/1.22	47/1.19 119.38/1.19	58/1.47 147.32/1.47
properties of the cured resins				
flexural modulus ((kg$_f$/cm²)) (N/m²)	(960) $94.1 \cdot 10^6$	(1020) $100.0 \cdot 10^6$	(980) $96.0 \cdot 10^6$	(1350) $132.3 \cdot 10^6$
CTE (x 10^{-5}/°C)	2.3	2.4	2.5	2.9
moisture resistance	+	+	xx	xx
thermal shock resistance	+	+	+	xx

Claims

1. A curable resin composition comprising

   (I) 100 parts by weight of a curable resin, and
   (II) 0.1 to 200 parts by weight of a cured organosiloxane comprising

   (A) particles of a cured organosiloxane composition having an average diameter of 0.1 to 200 micrometers, wherein said particles have immobilized on the surfaces thereof
   (B) amorphous silica exhibiting a surface silanol group density of at least 2 per 1 nm² (100 square angstroms), an average particle diameter not exceeding 1 micrometer, and a BET specific surface area of at least 50 m²/g.

2. The curable resin composition according to Claim 1, wherein ingredient (I) comprises at least one curable resin selected from epoxy resins, phenol resins, polyimide resins, and organosiloxane resins.

3. The curable resin composition according to Claim 1, wherein ingredient (II) is preparable by first heating a water-based dispersion comprising an organosiloxane composition curable by an addition or condensation reaction as

ingredient (A) and said silica as ingredient (B), wherein said dispersion is heated sufficiently to form said cured organosiloxane, and then removing the water from said dispersion.

4. The curable resin composition according to Claim 1, wherein ingredient (II) consists essentially of particles obtained by shear mixing ingredients (A) and (B).

5. The curable resin composition according to Claim 3, wherein from 0.05 to 30 parts of ingredient (B) is blended with 100 parts of ingredient (A).

6. The cured resin obtainable by curing the curable composition of Claim 1.

Patentansprüche

1. Härtbare Harzzusammensetzung, die die folgenden Bestandteile umfaßt:

   (I) 100 Gew.-Teile eines härtbaren Harzes und
   (II) 0,1 bis 200 Gew.-Teile eines gehärteten Organosiloxans, das

      (A) Teilchen einer gehärteten Organosiloxanzusammensetzung mit einem mittleren Durchmesser von 0,1 bis 200 µm, wobei auf den Oberflächen der Teilchen
      (B) amorphes Siliciumdioxid mit einer Oberflächensilanolgruppendichte von mindestens 2 pro 1 nm² (100 Å²), einem mittleren Teilchendurchmesser, der 1 µm nicht übersteigt, und einer spezifischen BET-Oberfläche von mindestens 50 m²/g immobilisiert ist, umfaßt.

2. Härtbare Harzzusammensetzung nach Anspruch 1, wobei der Bestandteil (I) mindestens ein härtbares Harz umfaßt, das aus Epoxyharzen, Phenolharzen, Polyimidharzen und Organosiloxanharzen ausgewählt ist.

3. Härtbare Harzzusammensetzung nach Anspruch 1, wobei der Bestandteil (II) durch anfängliches Erwärmen einer Dispersion auf Wasserbasis, die eine durch Additionsreaktion oder Kondensationsreaktion härtbare Organosiloxanzusammmsetzung als Bestandteil (A) und das Siliciumdioxid als Bestandteil (B) umfaßt, wobei die Dispersion ausreichend erwärmt wird, um das gehärtete Organosiloxan zu bilden, und anschließendes Entfernen des Wassers aus der Dispersion herstellbar ist.

4. Härtbare Harzzusammensetzung nach Anspruch 1, wobei der Bestandteil (II) im wesentlichen aus Teilchen besteht, die durch Vermischen der Bestandteile (A) und (B) unter Ausüben von Scherkräften erhalten wurden.

5. Härtbare Harzzusammensetzung nach Anspruch 3, wobei 0,05 bis 30 Teile Bestandteil (B) mit 100 Teilen Bestandteil (A) vermischt wurden.

6. Gehärtetes Harz, das durch Härten der härtbaren Zusammensetzung nach Anspruch 1 erhältlich ist.

Revendications

1. Une composition de résine durcissable comprenant

   (I) 100 parties en poids d'une résine durcissable, et
   (II) 0,1 à 200 parties en poids d'un organosiloxane durci comprenant

      (A) des particules d'une composition d'organosiloxane durcie ayant un diamètre moyen de 0,1 à 200 micromètres, lesdites particules portant, immobilisée sur leurs surfaces,
      (B) une silice amorphe présentant une densité de groupes silanol superficiels d'au moins 2 par nm², un diamètre moyen de particules ne dépassant pas 1 micromètre et une surface spécifique BET d'au moins 50 m²/g.

2. La composition de résine durcissable selon la revendication 1, dans laquelle l'ingrédient (I) comprend au moins une résine durcissable choisie parmi les résines époxy, les résines phénoliques, les résines polyimides et des

résines d'organosiloxane.

3. La composition de résine durcissable selon la revendication 1, dans laquelle l'ingrédient (II) peut être préparé en chauffant d'abord une dispersion aqueuse comprenant une composition d'organosiloxane durcissable par une réaction d'addition ou de condensation comme ingrédient (A) et ladite silice comme ingrédient (B), ladite dispersion étant chauffée suffisamment pour former ledit organosiloxane durci, puis en éliminant l'eau de ladite dispersion.

4. La composition de résine durcissable selon la revendication 1, dans laquelle l'ingrédient (II) consiste essentiellement en particules obtenues par mélange avec cisaillement des ingrédients (A) et (B).

5. La composition de résine durcissable selon la revendication 3, dans laquelle 0,05 à 30 parties d'ingrédient (B) sont mélangées avec 100 parties d'ingrédient (A).

6. La résine durcie pouvant être obtenue par durcissement de la composition durcissable de la revendication 1.